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Title:  
SYSTEM FOR MINIMIZING INCENDIARY  
STATIC ELECTRICAL DISCHARGE.

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SYSTEM FOR MINIMIZING INCENDIARY  
STATIC ELECTRICAL DISCHARGE

Field of the Invention

The present invention relates to a system for treating surfaces to suppress the incendivity of static discharges and more particularly to a system for treating surfaces and textile fabric materials to obtain improved antistatic properties in flexible intermediate bulk containers.

Background of the Invention

Containers formed of flexible fabric are being used in commerce more and more widely to carry free-flowable materials in bulk quantities. Flexible intermediate bulk containers have been utilized for a number of years to transport and deliver finely divided solids such as cement, fertilizers, salt, sugar, and barite, among others. Such bulk containers can in fact be utilized for transporting almost any ~~of~~ type of free-flowable finely divided solid. The fabric from which they are generally constructed is a weave of a polyolefin, e.g., polypropylene, which may optionally receive a coating of a similar polyolefin on one or both sides of the fabric. If such a coating is applied, the fabric will be non-porous, while fabric without such coating will

be porous. The usual configuration of such flexible bulk containers involves a rectilinear or cylindrical body having a wall, base, cover and a closable spout secured to extend from the base or the top or both.

Such containers are handled by placing the forks of forklift hoist through loops attached to the container. The weight of such bulk container when loaded is usually between 500 pounds and 4,000 pounds, depending upon the density of the material being transported.

Crystalline (isotactic) polypropylene is a particularly useful material from which to fabricate monofilament, multifilament or flat tape yarns for use in the construction of such woven fabrics. In weaving fabrics of polypropylene, it is the practice to orient the yarns monoaxially, which may be of rectangular or circular cross-section. This is usually accomplished by hot-drawing, so as to irreversibly stretch the yarns and thereby orient their molecular structure. Fabrics of this construction are exceptionally strong and stable as well as being light-weight.

Examples of textile fabrics of the type described above and flexible bulk containers made using such fabrics are disclosed in U.S. Pat. Nos. 3,470,928, 4,207,937, 4,362,199 and 4,643,119, the disclosures of which are incorporated herein in their entirety by reference.

It has been found that the shifting of specific materials within the bulk container as well as particle separation between the material and the container during loading and unloading of the container causes triboelectrification and creates a build-up of static electricity on the container walls. Also, highly charged material entering the bulk container can create a build-up of static electricity on the container walls. Electrostatic discharges from the charged container can be dangerous in dusty atmospheres or in flammable solvent vapor atmospheres and can be quite uncomfortable to workers handling such containers in non-flammable atmospheres.

One proposed technique for dissipating electrostatic charges that might otherwise build up during the handling of bulk containers is to provide a fabric wherein conductive yarns are interwoven with the other yarns used in the weaving of the fabric. The conductive yarns are interconnected and one or more connection

points are provided for an external ground source. For example, Canadian Patent 1,143,673 and U.S. Patent No. 4,431,310, the disclosures of which are incorporated herein by reference, disclose a fabric construction based on polyolefin yarn having conductive fibers in the yarns. Alternatively, the fabric may be coated with a layer of plastic film having an outer metalized surface. See United States Patent No. 4,833,088, incorporated herein in its entirety by reference for an example of such a fabric.

One of the disadvantages of these types of construction is that the container made therefrom, if not grounded, may generate a spark discharge capable of igniting flammable vapors or dust clouds and therefore must be grounded during the fill and emptying operations to provide a path for electrical discharge.

Another proposed technique for dissipating electrostatic charges is the addition of an antistatic agent. The antistatic agent, e.g., a polyol ester, may be in the form of a thermoplastic coating and/or may be added to the polypropylene yarn. One example of a yarn containing an antistatic agent additive is disclosed in United States Patent No. 5,071,699, the disclosure of which is incorporated herein in its entirety by reference. Other

antistatic agents that can be used are amines, amides, carbon black, Hyperion graphite Fibrils™, conductive polymers such as polyaniline, and elemental metals such as aluminum.

The present invention overcomes the problems of the prior art by providing new antistatic flexible fabrics designed to minimize resulting incendiary static discharges without requiring a physical electrical ground.

#### SUMMARY OF THE INVENTION

An object of the invention to provide an antistatic flexible fabric comprising interwoven polypropylene yarns optionally containing an antistatic agent and a coating on one or both sides consisting of a thermoplastic polymers composition optionally containing an antistatic agent.

A further object of the invention is to provide an antistatic fabric of polypropylene yarns containing a coating of a polypropylene and polyethylene blend on one or both sides and a layer of cellulose material laminated to either side.

A still further object of the invention is to provide an antistatic fabric containing a fabric body of interwoven

polypropylene yarns that contain a polyol ester as an antistatic and which are coated on both sides with a polypropylene or polypropylene and polyethylene blend that contains from 1 to 15% of an antistatic agent.

Another object of the invention is to provide a FIBC constructed from each of the antistatic fabrics.

Additional objects and advantages of the invention will be set forth in part in the discussion that follows, and in part will be obvious from the description, or may be learned by the practice of the invention. The object and advantages of the invention will be obtained by means of the instrumentalities and combinations particularly pointed out in the appended claims.

To achieve the objects and in accordance with the purpose of the invention, as embodied in broadly described herein, the present invention provides for anti-static flexible fabric materials formed from woven, axially oriented crystalline polypropylene yarn. In one embodiment of the invention, the fabric is further characterized as having a coating of a flexible, thermoplastic polymer on one side of the fabric and having cellulose material laminated to either side.

In another embodiment, the fabric is further characterized as having a coating of a flexible, thermoplastic polymer on both sides of the fabric. Antistatic properties are imparted to the fabric by formulating the thermoplastic coating to contain from about 1 to about 15% by weight of a polyol ester (preferably glycerol) of a  $C_{10}$  to  $C_{28}$  fatty acid. Other antistatic agents that can be used are amines, amides, carbon black, Hyperion graphite Fibrils™, conductive polymers such as polyaniline, and elemental metals such as aluminum. The polypropylene yarn may optionally itself also contain a lesser amount of the polyol ester of a  $C_{10}$  to  $C_{28}$  fatty acid to provide a fabric having even more enhanced antistatic properties. The other antistatic agents previously described can also be used in this manner.

A particular advantage of the fabrics of the present invention is that specific surface resistivities e.g., between  $10^9$  and  $10^{12}$  ohm/square are achieved and when containers are normally constructed therefrom need not be grounded during filling and emptying operations. As static charges are generated, the electrostatic charge can flow across the fabric and dissipate as low energy corona or low energy static discharges in the discharge channel. Thus, containers constructed from the fabrics of the

present invention, ~~is~~, under certain conditions, <sup>will NOT</sup> ~~incapable of~~ producing <sup>any</sup> incendiary static discharge, ~~without~~ <sup>AND DOES NOT REQUIRE</sup> the use of a physical electrical ground.

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#### BRIEF DESCRIPTION OF THE DRAWINGS

FIG 1 is a schematic of the body of woven yarn material used in forming a fabric according to a preferred embodiment of the invention.

FIG. 2 is a schematic of a laminated structure according to a first preferred embodiment of the invention.

FIG. 3 is a schematic of a laminated structure according to a second preferred embodiment of the invention.

FIG. 4 is a schematic of a laminated structure according to a third preferred embodiment of the invention.

FIG. 5 is a schematic of a laminated structure according to a fourth preferred embodiment of the invention.

DETAILED DESCRIPTION OF PREFERRED  
EMBODIMENT OF THE INVENTION

Reference will now be made in detail to preferred embodiments of the invention, which, together with the following examples, serve to explain the principles of the invention.

Referring to FIG. 1, the fabric material 10 is composed of a plurality of vertically extending flat warp yarns 11 interwoven with a plurality of horizontally extending flat weft or filling yarns 12. These yarns are interwoven by techniques well known in the art on a textile loom to form a sheet-like material relatively free of interstices. The tightness of the weave depends on the end use. Where the fabric is to be used to form containers for holding large particle size bulk material such as tobacco or pellets, then a fairly open weave or mono or multifilament yarn may be used in a count range of from about 1000 to 3000 denier in each weave direction.

In one preferred embodiment, the yarns are composed of a tight weave of axially oriented polypropylene flat tape material having a preferred thickness of from about 0.5 to about 2 mils and a preferred width of from about 50 to about 250 mils. It will be appreciated that by use of the flat tape yarns, maximum coverage is obtained with the least amount of weaving since it requires

relatively few flat yarns per inch to cover a given surface as compared to yarns of circular cross section. It is important that the ribbon-like yarns be highly oriented mono-axially in the longitudinal direction or biaxially in the longitudinal and transverse directions. This is accomplished by so drawing the flat yarn or the web from which flat yarn ribbons are slit, so as to irreversibly stretch the yarn or web, thereby orienting the molecular structure of the material. In biaxially oriented yarns or sheeting, the material is hot or cold-stretched both in the transverse and longitudinal directions, but for purposes of the present invention, it is desirable that the orientation be carried out mainly in the longitudinal direction.

When axially oriented polypropylene yarns are interwoven, they cross over in the warp and weft directions, and because of their high tear and tensile strength, as well as their hydrophilic properties, the resultant fabric is highly stable. Thus the bag, if properly seamed, is capable of supporting unusually heavy loads without sagging or stretching of the walls of the bag.

FIG. 2 represents another embodiment of the present invention. Layer 21 is a weave of polypropylene flat ribbon yarns of the type described above. The polypropylene weave is then

coated on one side with a polyolefin polymer blend 22. In addition, a layer of cellulose material 24 is laminated to the polypropylene layer on the side opposite of the polyolefin coating. The cellulose material is laminated using a hot melt adhesive 24. A typical hot melt adhesive is Nylco E9 pressure sensitive adhesive.

FIG. 3 represents another embodiment of the present invention. Layer 31 is a weave of polypropylene flat ribbon yarns of the type described above. The polypropylene weave is then coated on one side with a polyolefin polymer blend 32. At the same time the weave is being coated, a layer of cellulose material 33 is laminated to the polypropylene layer using the polyolefin polymer blend as the adhesive.

FIG. 4 represents another embodiment of the present invention. Layer 41 is a weave of polypropylene flat ribbon yarns also of the type described above that contains a coating of thermoplastic polymer material 42, 43 adhered to both sides of the fabric.

Fig. 5 represents one embodiment of the present invention. Layer 51 is a weave of polypropylene flat ribbon yarns of the type

described above. A layer of cellulose material 52, 53 is laminated each side of the polypropylene.

The purpose of the thermoplastic coating 22 in FIG 2 and 42, 43 in FIG. 4 is primarily to seal the interstices of the yarn weave to prevent leakage of any finely divided contents of containers made from the fabric, and also to impart moisture barrier properties to containers or in other fabric applications such as tarpaulin or tent fabrics. In the present invention, the thermoplastic coating may also serve as a dispersing base for an antistatic agent which helps impart antistatic properties to the fabric, as more fully discussed below.

The thermoplastic coating may be composed of any thermoplastic polymer composition which is sufficiently non-brittle so that the flexible characteristics of the woven fabric are not seriously diminished and which is adherable to the polypropylene yarn material forming the fabric base. Preferred thermoplastics forming the coating include polypropylene, polyethylene, or blend thereof, e.g., 80%/20% respectively, polyisobutylene copolymers of ethylene and a lower olefin such as propylene or butene, as well as mixtures of such polymers. One preferred coating contains a major proportion of polypropylene.

The coating may also contain other additives such as fillers, UV absorbers, plasticizers and like ingredients normally formulated into polymeric coatings.

The thermoplastic coating applied to one or both surfaces of the woven fabric by techniques is known in the art such as extrusion coating, dip coating and spray coating. Generally speaking, the coating may be applied to a dry coating thickness within the range of from about 0.5 to about 3.0 mils, preferably from about 0.8 to about 1.5 mils.

Antistatic properties are imparted to the fabric structures depicted in FIG. 3 of this invention by the inclusion of a minor amount of a polyol ester of a  $C_{10}$  to  $C_{28}$  monocarboxylic acid or mixture of such acids into the thermoplastic coating formulation, and optionally into both the thermoplastic coating formulation and the polypropylene formulation used to prepare the fabric yarn material. Suitable polyols from which these esters may be derived include ethylene glycol, propylene glycol, glycerol, pentaerythritol and like materials. Preferred esters include mixtures of mono-, di, and triglycerides (glycerol esters) of  $C_{10}$  to  $C_{28}$  monocarboxylic acids such as decanoic, lauric, myristic, palmitic or stearic acids, as well as mixtures of such esters.

The most preferred esters are esters of  $C_{10}$  to  $C_{22}$  monocarboxylic acids, and are most preferably stearyl monoglycerides containing at least about 80% by weight of the glycerol monostearate monoester. A preferred group of anti-static compounds are polyol partial fatty acid esters marketed by the Henkel Company under the trade designation DEHYDAT 8312 and DEHYDAT 8316.

In general, good antistatic properties may be obtained by the inclusion of from about 1.0% to about 15% by weight of the antistatic agent into the coating formulation, based on the weight of polymer in the coating. More preferred addition levels of antistatic compound are around 5% by weight being most preferred.

The antistatic compound may also be incorporated into the polypropylene composition used to prepare the yarn material and at levels of from 0 to about 2% by weight based on the content of polypropylene polymer. Best results are achieved where the antistatic compound is present in the yarn material at levels less than it is present in the coating composition. The preferred content of antistatic compound when present in the yarn material ranges from about 0.05 to about 1% by weight, with about 0.1 to about 0.8% by weight being most preferred.

The antistatic additive may be mixed with the base polymer in the molten state or with polymer pellets in an extruder. Preferably the antistatic compound is first formulated into a concentrate also containing an olefin polymer such as polyethylene or polypropylene and any other ingredients to be added such as a UV-absorber, plasticizer, filler, dye or the like, and this concentrate is then thoroughly admixed with the base polymer.

It is to be understood that the application of the teaching of the present invention to a specific problem will be within the capabilities of one having ordinary skill in the art in light of the teachings contained herein. Examples of the products of the present invention and processes for their operation and their use appear in the following examples.

#### EXAMPLE 1

Warp and weft yarn material for use in preparing a woven fabric was prepared by forming a mixture comprising about 96 parts by weight of a crystalline polypropylene having a melt flow index of 2-3 and about 4 parts by weight of an antistatic concentrate which contained a mixture of low density polyethylene, polypropylene having a melt flow index of 12, an ultra violet absorber, a filler, and a quantity of antistatic agent identified

in Table 1 sufficient to provide the indicated content of antistatic in the final polymer formulation.

The formulation was extruded into a film, slit and drawn to provide 1060 denier warp and 2500 denier weft (or fill) fibrillated strips of monoaxially oriented polypropylene. The processing conditions were generally as follows:

Extrusion temperature	255-265° C
Quench gap	1-3 inches
Quench temperature	25-35° C
Orienting temperature	160-190° C
Annealing temperature	145-155° C
Draw ratio	6:1-8:1

A loom was set up to produce three 42" wide fabric cells using 2994 warp ends. The strips produced above were woven to produce a solid fabric material composed of 1060 denier warp yarns and 2500 denier weft or fill yarns, with about 10-12 yarn ends per linear inch of fabric.

#### EXAMPLE 2

A polypropylene fabric was constructed according to the method described in Example 1 except the fabric contained only

crystalline polypropylene and no antistatic concentrate. The polypropylene was formulated and woven according to the methods described in Example 1.

### EXAMPLE 3

Various coating compositions for use on the woven fabrics of Examples 1 and 2 were constructed. The coatings were based on a polymer mixture of about 70-75% by weight of polypropylene having a melt flow index of 30-40, about 15-25% by weight of low density polyethylene having a melt flow index of 6-9, and an ultraviolet absorber. In some embodiments, a quantity of antistatic compound as indicated in Table 1 was added to the coating. In other embodiments, the coatings were a polypropylene - polyethylene blend.

The coatings were extrusion-coated through a slot die onto the fabric material prepared in accordance with Examples 1 and 2 by passing a moving web of the fabric under a hot melt of the coating from the extruder die, followed by cooling the composite to solidify the coating. The dry coating thickness was between 0.8 and 1.5 mils.

#### EXAMPLE 4

In one embodiment of the present invention, the fabric was coated on one side with the polypropylene - polyethylene blend and laminated on the other side with cellulose material. The cellulose material is laminated to the uncoated side using a hot melt adhesive such as Nylco E9. An FIBC container was then constructed with the paper side on the outside of the container.

#### EXAMPLE 5

In one embodiment of the present invention, the fabric is coated on one side with the polypropylene - polyethylene blend. At the same time the weave is being coated, a layer of cellulose material is laminated to the polypropylene layer using the polypropylene - polyethylene blend as the adhesive.

#### EXAMPLES 6-10

Various samples of fabric prepared in accordance with Examples 1-5 above were evaluated for surface resistivities.

Surface resistivity measures the surface resistance to electron flow across the fabric surface between two electrodes placed on the surface of the fabric specimens. The measurement is the ratio of the direct voltage applied to one electrode to that

portion of the current between the electrodes, which is primarily in a thin surface layer. This test was conducted in accordance with ASTM D-257-78.

Examples 6-10 were tested according to the following method:

The FIBC was mounted onto a filling stand where polypropylene pellets were loaded into the FIBC while being naturally or artificially charged to very high levels. The highest static levels achieved were essentially the highest practical static levels possible for polypropylene pellets FIBC material under normal conditions and were intended to create intense extreme conditions for static discharges from the FIBC surface. During filling, static field measurements were taken and a "gas ignition probe" was brought toward the fabric. This probe used a propane/air mixture which has an ignition energy (MIE) approximately 0.25 mJ which is equivalent to typical minimum ignition energies of common flammable vapors. For dust explosions, the minimum ignition energy is normally higher than that for vapors. The FIBC was evaluated at ambient humidity, usually 50 to 55% relative humidity (RH) and at low humidity, usually between 15 to 30% RH. In general for chemical antistats,

as relative humidity decreases the static protective properties also decrease.

Results of the evaluation of antistatic properties for fabric structures having the structure and composition indicated in Table 1 are reported in Table 1.

TABLE 1

Example	Compound	%	Compound	%	# of Sides	Plain		Coated Side	Surface Tested	Surface Resistivity, $\Omega/\square$	
						Side	Side			Low RH	Ambient RH
1	GMS*	0.15	No Coating	---	---	---	---	---			
2	None	---	No Coating	---	---	---	---	---			
3	None	---	None	---	---	---	---	---	Fabric	---	$>10^{13}$
4	None	---	None	---	One	Yes	---	---	Cellulose	$1.4 \times 10^{11}$	$3 \times 10^9$
5	None	---	None	---	One	---	---	Yes	Cellulose		$2.9 \times 10^{11}$
6	GMS	0.15	Henkel	4	Two	---	---	---	Coating	$7 \times 10^{11}$ - $2.2 \times 10^{12}$	$1.6 \times 10^9$ - $5.6 \times 10^{12}$
7	GMS	0.15	Henkel	10	Two	---	---	---	Coating	$2 \times 10^{12}$	$3.4 \times 10^{11}$
8	GMS	0.15	Ampacet	10	Two	---	---	---	Coating	$1.7 \times 10^{11}$ - $9.7 \times 10^{11}$	$2.4 \times 10^9$ - $4 \times 10^{10}$
9	GMS	0.15	Ampacet	7	Two	---	---	---	Coating	$2.6 \times 10^{11}$ - $2.4 \times 10^{12}$	$5.4 \times 10^9$ - $4 \times 10^{10}$
10	GMS	0.15	Graphite Fibrils™	3	One	---	---	---	Coating	---	$2 \times 10^6$ - $3 \times 10^7$

\*GMS is Glyceral MonoStearate

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As indicated in Table 1, Example 3 is a control FIBC containing no antistatic compounds or cellulose materials. Examples 8, 9, and 10 are samples containing the specified amounts of antistat. In each case these examples produced incendiary discharges and failed in the filling tests by regularly igniting the propane/air mixture from the gas ignition probe.

Example 4 passed a limited number of filling tests at both humidities <sup>AT</sup> and static electric fields levels where gas probe ignitions were observed for fabric used in Example 3. Example 6, under certain circumstances, did not ignite the gas probe at both humidities. Example 7, under the same circumstances as Example 6, did not ignite the gas probe at ambient humidity. Example 7 was not tested at low humidity. Example 5 was not constructed into a FIBC.

The test data indicates that the best static control properties, in the range of relative humidities previously described, are achieved with a surface resistivity range between  $10^9$  and  $10^{12}$  ohm/square ( $\Omega/\square$ ).

The use of certain materials having a surface resistivity range between  $10^9$  and  $10^{12}$  ohm/square results in a system having low incendiary static discharge. While the invention as described herein is primarily directed to the use of such a material in the

formation of an antistatic fabric, the certain materials may also be used in other circumstances when it is desirable to dissipate static electricity and minimize resulting incendiary static discharge. An example of such a use is the inside of a silo or grain container, conveying equipment, or other applications where electrostatic discharge will result in a spark discharge.

While the invention has been described with reference to specific embodiments, it will be apparent to those skilled in the art that many alternatives, modifications, and variations may be made. Accordingly, it is intended to embrace all such alternatives, modifications, and variations that may fall within the spirit and scope of the appended claims.

What is claimed as new and desired to be protected by Letters Patent of the United States is: